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CHAPTER 3

Trends in Output per Worker

The output of the economy may be viewed as the product of employment of workers and output per worker. We have discussed changes in employment in the preceding chapter; let us now turn to changes in output per worker.

Output per worker is determined by two factors: first, the productivity of labor; second, the quantity and quality of the other resources cooperating with labor. Output per worker rises when the workers are more skilled and work with greater intensity, and it rises also when they are given better equipment, more efficient plant-layouts, and better materials.

We may, as a rule, view an increase in output per worker as evidence of economic progress whether it stems from improvements in labor or improvements in the cooperating resources. A general increase in output due to improvements in the productivity of labor is an unmixed blessing if it comes from better training, better minds, and better physiques: we are in effect adding to the hands that run our economic system without—as the classical economists sometimes believed necessary—adding to the mouths that consume its product. Similarly, increases in output per worker achieved by increasing the quantity or improving the quality of cooperating resources imply that we have extended our mastery over nature or over ignorance: we can live better without working harder.

The index is not infallible, of course. To the extent, for example, that increases in output per worker are obtained by persuading the workers to strike a pace that depletes their reserves—as was at times the case during the war—the increases are promises of economic retrogression rather than signs of economic progress. Or again, if we increase capital per worker

by the expedient of utilizing less of the labor force, we may be moving backward instead of forward. These and other qualifications are of some importance, and will be discussed below, but they are not likely to upset the interpretation of long-run increases in output per worker as a sign, indeed a rough measure, of economic progress.

We must remember that a recorded increase in output per worker may be due to either labor or the cooperating resources. The temptation to attribute an increase to only one source—usually labor, in part because it is more easily measured—is strong but must be resisted. The attribution of all changes in total output to one of the inputs is an error. And the error may lead to economic waste, for if all changes in output are attributed to one input, there may be no inducement to increase the quantity or improve the quality of the cooperating resources.

Changes in Output per Worker

By dividing the rough index of aggregate output (Table 2) by that of aggregate employment (Table 9), we derive a series for output per worker rising from 100 in 1899 to 222 in 1939. That is, output per worker in the six industries rose on

1899	*1909*	*1919*	*1929*	*1939*
100	113	127	189	222

the average 122 percent, an average of 14 percent each decade except in the 'twenties, when the increase was almost 50 percent. If labor were measured in man-hours instead of workers, the increase in output per unit of labor would be about 200 percent.[1] The shift to man-hours would also reduce the bulge in the rate of increase in the 'twenties, because hours of labor fell less in this decade than in the other three decades.[2]

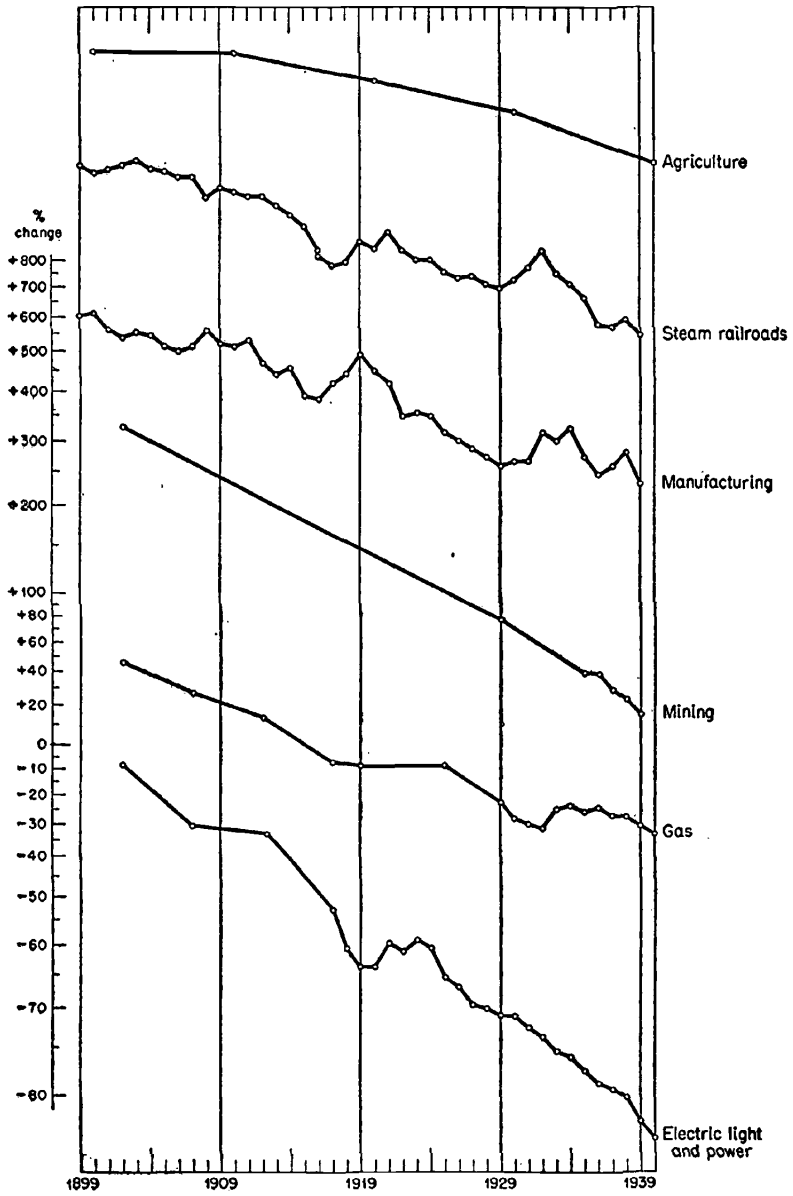
Labor requirements per unit of output declined markedly and persistently (Chart 6). The smallest reduction, in agri-

[1]Fabricant, *Occasional Paper 23*.

[2]In manufacturing the average hours of work per week fell 4, 9, 3, and 18 percent respectively in the four decades.

CHART 6

Indexes of Employment per Unit of Output in Six Industries 1899 – 1940



culture, was 40 percent.[3] Of the six industries, gas alone experienced a pronounced decline in the rate of decrease in labor requirements.

In other words, if the 1940 products of these industries could have been produced with the techniques of 1900, they would have required the entire labor force, working more hours than were customary in 1940. Instead, these outputs were produced by less than half of the 1940 labor force.

This is a somewhat dramatic method of summarizing the enormous gains that accumulate almost surreptitiously through technical advance. But the gains need to be dramatized. The losses resulting from widespread unemployment of resources are much more obvious. They are serious and no one will deny the urgency of finding ways to minimize them. There is, however, a dangerous tendency to talk as if the avoidance of unemployment were the only problem of social policy—unemployment must be avoided 'at all costs'. Unfortunately, it is difficult to harmonize the objectives of full employment and rapid economic progress. This is not to argue that unemployment should be accepted fatalistically as the price of progress, but it does argue strongly for giving due consideration to progress in devising measures to combat unemployment. The fundamental economic problem is not merely to maximize employment—this goal might possibly be attained by freezing the economy at a moment of full employment—but also to achieve a large and growing output.

Output per Worker as a Measure of Progress

The index of output per worker is the quotient of indexes of output and employment, and hence is heir to all the objections that can be raised against them. Indeed the index of output per worker is likely to be more sensitive to errors of measurement because opposite errors in the indexes of

[3]The expression, workers per unit of output, is used at this point in preference to the alternative (and reciprocal) expression, output per worker, because of graphical convenience.

quantity and employment are compounded: a 10 percent overstatement of output and a 10 percent understatement of employment will lead to a 22 percent overstatement of output per worker. Any disparity in the coverage of output and employment—and it is never possible to make them correspond exactly—is an additional source of error. But these are obvious limitations, and need not be elaborated.

A second type of qualification must be attached to short-run fluctuations in output per worker. Output per man-hour in the automobile industry fell 16.7 percent from 1929 to 1931, but surely this does not mean that more primitive techniques were used in the later year. The dates are a sufficient clue to the explanation: in many industries output will fluctuate more widely than employment because the entrepreneur cannot (for contractual, technical, or other reasons) make proportionate changes in his labor force. We should recognize also the difficulty of achieving comparability between output and employment in short periods; for example, the considerable fluctuations in goods in process during a cycle are not reflected in the usual measures of output. Short-run changes in output per worker cannot be interpreted as measures of economic progress.

The third type of qualification arises because we are comparing all output with only one input. If an entrepreneur substitutes other resources for labor because labor has become more expensive, and not because the other resources have become cheaper or improved, output per worker necessarily rises. Yet efficiency may have fallen, whether measured by the entrepreneur's costs or by social costs (of which something will be said presently). The phenomenon can be widespread: output per worker can be rising in every industry while national income is falling. This line of thought suggests that the index of output per worker will be more accurate as a measure of economic progress the greater the importance of labor in the industry. We examine the suggestion more closely below.

Patterns of Changes in Output per Worker

Indexes of output per worker are a relatively recent acquisition and their properties deserve much study. One of these properties is the pattern of changes in output among the various industries. Is there little or much dispersion in changes in output per worker among industries? Do industries maintain a fairly stable pattern or do their relative positions with respect to the growth of output per worker fluctuate widely? These and similar questions are pertinent to numerous current applications of the indexes. For example, it is often argued that wage rates should follow output per worker. But unless most firms (and therefore industries) have approximately equal changes in output per worker, this criterion may conflict with equality of wages within an occupation. Or again, if output per worker does not increase steadily, but fluctuates widely about its trend, the current procedures for forecasting income and employment require some revision.

The pattern of changes in output per worker may be glimpsed from data on thirty-two manufacturing industries for which Fabricant has presented continuous series back to 1899. The frequency distributions of percentage changes in output per worker per year have very wide spreads (Table 12).[4] The standard deviation of the percentage increases in output never fell below 3.2 percent and in half the periods equaled or exceeded 5 percent. There is no apparent tendency for dispersion to decline. The variation among all manufacturing industries was doubtless larger, for our restriction of manufacturing industries to those for which data were available for forty years excludes most new industries.

The effect of variation in working hours plays an uncertain part in this picture of diversity, hence comparable indexes were computed for 13 of the 32 industries for which

[4]The annual percentages are calculated by halving the biennial changes and taking a fifth of quintennial changes; use of compound interest formula would have reduced the scatter inappreciably.

TABLE 12

Frequency Distribution of Thirty-two Manufacturing Industries by Percentage Changes in Output per Worker per Year, 1899-1939

PERCENTAGE CHANGE IN OUTPUT PER WORKER	1899-1904	1904-09	1909-14	1914-19	1919-21	1921-23	1923-25	1925-27	1927-29	1929-31	1931-33	1933-35	1935-37	1937-39
−18 to −15					1				1	1				
−15 to −12										2		1		
−12 to −9										3	2			
−9 to −6				3	1						8	3		
−6 to −3	1	2		3	2	1		1	1	4	5	3		
−3 to 0	8	3	6	12	7	1	3	2	3	4	9	4	4	2
0 to 3	17	13	14	8	4	3	6	17	7	4	8	9	12	7
3 to 6	1	10	8	3	3	7	13	5	11	11		5	6	12
6 to 9	3	1	3	2	5	8	2	6	3	2		2	8	5
9 to 12	1				4	2	6	1	3				2	2
12 to 15	1	1		1	3	8	1		1	1		2		4
15 to 18		1			1	2	1		2			2		
18 to 21		1			1							1		
21 plus			1*											
Average	1.6	3.4	3.0	0.	4.2	8.0	5.4	3.1	4.0	−.8	−3.2	2.3	3.6	5.4
Standard deviation	3.8	5.0	6.6	4.2	7.6	5.4	4.3	3.2	6.2	7.0	3.6	7.4	3.5	4.3

*36.2

man-hours were known from 1929 to 1939. The comparison indicates, as one would expect, that output per man-hour rose more rapidly than output per worker except in the period when hours were lengthened, 1935-37 (see Table 13). But the picture of diversity persists; indeed the standard deviation of percentage changes in output per man-hour are larger in four of the five periods. It seems clear that the average change in labor productivity in a period is approached by relatively few industries.

TABLE 13

Annual Percentage Changes in Output per Worker and per Manhour, and Standard Deviations of these Changes Thirteen Manufacturing Industries, 1929-1939

	1929-31	*1931-33*	*1933-35*	*1935-37*	*1937-39*
% Change in Output per					
Worker	−.4	−1.6	3.2	2.7	5.2
Manhour	3.8	3.7	6.8	1.3	5.8
Standard Deviation of					
% Changes in Output per					
Worker	5.4	3.0	7.0	2.5	4.0
Manhour	5.2	3.5	7.7	3.1	4.6

Nor is there strong evidence of a stable pattern among the industries. If the 32 industries are ranked according to the percentage change in output per worker within each of the 14 periods for which data are available, one may test the existence of a stable pattern by an analysis of ranks.[5] This test does not reveal a systematic pattern; the probability of as large or a larger departure from a random distribution of ranks by industries under random sampling is one-tenth. In 13 of these industries for which output per man-hour is available since 1929, the test reveals no stability in the ranks of changes in either output per man-hour or output per man.[6]

If the indexes are accurate, we may conclude that increases in output per worker are not stable through time, either within or among individual manufacturing industries.

The Measurement of Changes in Efficiency

Since output per worker, useful though it be, is an incomplete measure of economic progress, can we go further and measure changes in the efficiency with which all resources are used? Efficiency is usually defined as

$$\frac{\text{Output}}{\text{Input of Labor} + \text{Input of Other Resources}},$$

where, for convenience, we shall call these other resources (materials, capital equipment, management, etc.) 'capital'. All the quantities are flows during an equal period—annual product, man-years, and annual services of capital. They must be measured in comparable physical units; in value terms the ratio of receipts to expenditures is (with certain definitions) unity.

But we are interested in changes in efficiency, not its abso-

[5]See Milton Friedman, 'The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance', *Journal of the American Statistical Association*, Dec. 1937, pp. 675-701.

[6]The probabilities of as large or larger a departure from a random distribution of industrial ranks is almost .7 when the rankings are by either output per worker or per man-hour.

lute magnitude. We can measure changes in efficiency if, in addition to the indexes of output and employment we already possess, we can somehow find (1) the ratio of the quantity of capital services in one period to the quantity in another period, and (2) the ratio of the quantity of labor services to that of capital services in either period.[7]

The first requirement, the relative change in the flow of capital services in real terms, cannot be estimated at all precisely. The net book value of capital assets in current dollars has been estimated by Fabricant for 1904 and 1937 in the major manufacturing groups, but unfortunately he necessarily omits land and rented equipment, as well as management, which we lump with capital. Nor do we have any information on the extent to which the assets were used in the two years. Fabricant estimates that the appropriate price index to deflate the 1937 values to a 1904 base is about 180. This deflator registers only price changes, whereas we would like to take some account also of quality changes. Moreover, the index refers to all manufacturing, and the appropriate deflators for individual industry groups might vary considerably.

Serious difficulties are also encountered in seeking the ratio between labor and capital services. If we can invoke Marshall's principle of substitution—that the entrepreneur adjusts the quantities of various productive services so that at

[7]The ratio of efficiency in period 2 to efficiency in period 1 is given by

$$\frac{Q_2}{Q_1} \bullet \frac{C_1 + L_1}{C_2 + L_2},$$

where Q, C, and L represent quantities of output, capital, and labor respectively, and the subscripts refer to the two periods. This expression can be rewritten as

$$\frac{Q_2}{Q_1} \bullet \frac{\frac{C_1}{C_2}\frac{C_2}{L_2} + \frac{L_1}{L_2}}{\frac{C_2}{L_2} + 1},$$

whence it is clear that we need to know C_1/C_2 and C_2/L_2 (or, alternatively, C_1/L_1, as can be seen by dividing numerator and denominator of the first expression by L_1).

the margin he obtains equal product per dollar of expenditure on each—the ratio of payroll to other value-added is an estimate of the ratio of labor to capital.[8]

But Marshall's law pertains to competitive equilibrium, and our data refer to single years in which departures from equilibrium may have been large. Evidence offered below, however, suggests that the ratio of labor services to capital services is easier to estimate with tolerable accuracy than the relative change in capital in real terms between periods.

The changes in output per worker and output per unit of capital that one may construct along these lines are given in Table 14; efficiency of all inputs is the weighted average of these changes, using the 1937 ratio of value-added-other-than-wages to wages as the relative weight.[9] The ranks of the industries by gains in efficiency differ somewhat from those by increase in output per worker; the largest differences occur in petroleum and coal products, where a large increase in capital offsets a large increase in output per worker, and in leather products, where the reverse takes place.[10] The general correspondence between efficiency and output per worker is

[8]By the law of substitution, if MP_l and MP_c are the marginal products of labor and capital respectively, and p_l and p_c are their prices,

$$\frac{MP_l}{p_l} = \frac{MP_c}{p_c};$$

and if L and C are quantities of labor and capital respectively, the ratio of L to C in physical (product) terms is

$$\frac{L\,MP_l}{C\,MP_c} = \frac{Lp_l}{Cp_c}.$$

[9]The ratio of efficiency in period 2 to that in period 1 may be written,

$$\frac{1}{\frac{C_2}{L_2} + 1}\left[\left(\frac{Q_2C_1}{Q_1C_2}\right)\frac{C_2}{L_2} + \left(\frac{Q_2L_1}{Q_1L_2}\right)\right].$$

The terms within parentheses are the ratio of output per unit of capital in period 2 to that in period 1 and the ratio of output per worker in period 2 to that in period 1. The weights are C_2/L_2 and 1.

[10]The rank correlation between changes in efficiency and output per worker is .74.

TABLE 14

Percentage Changes in Output per Worker, Output per Unit of Capital, and Efficiency in the Use of all Resources in Twelve Manufacturing Industries, 1904-1937

	PERCENTAGE CHANGE OUTPUT PER		
	Worker	Unit of Capital	Efficiency
Transportation equipment	308	130	228
Tobacco products	445	100	175
Printing and publishing	156	142	147
Chemical products	147	119	126
Paper products	122	36	69
Beverages	44	75	69
Leather products	17	109	61
Textile products	42	73	57
Petroleum and coal products	239	−45	39
Iron and steel products	54	28	38
Food products	27	17	21
Forest products	6	−42	−18

due in part to the importance of labor (for wages vary from 20 to 50 percent of value-added) and in part to a weak association between changes in output per worker and output per unit of capital.[11]

Some check on the reliability of the 1937 estimate of the ratio of capital services to labor services is afforded by comparing it, and the resulting index of efficiency, with that computed from 1904 data. Because of changes in Census classification, the comparison can be made readily for only six industries (Table 15). The effects of shifting to the earlier

TABLE 15

Ratio of Capital to Labor and Percentage Change in Efficiency, 1904-1937, Based on 1904 and 1937 Value-Added Data Six Manufacturing Industries

	RATIO OF CAPITAL TO LABOR		% CHANGE IN EFFICIENCY	
	1904 Data	*1937 Data*	*1904 Data*	*1937 Data*
Tobacco products	2.25	3.64	150	175
Printing and publishing	2.23	2.37	147	147
Paper products	1.43	1.78	64	69
Leather products	1.03	.90	50	61
Petroleum and coal products	2.05	2.33	−24	39
Forest products	1.14	.99	−26	−18

[11]The rank correlation between changes in output per worker and output per unit of capital is .38.

ratio of capital to labor are small except in petroleum and coal products, where the index of efficiency is sensitive to the weight used to combine outputs per unit of labor and capital because of the great difference between their movements.

It cannot be claimed that these rough estimates of changes in efficiency have much more than illustrative value. Yet they should serve to remind us that it is important to measure all inputs of resources before we draw conclusions with respect to changes in efficiency. Even the present, very imperfect measures of changes in output per unit of capital give, I think, a more accurate picture of changes in efficiency than one could obtain from data on output per worker alone.